A Deep Learning Framework for Predicting the Mechanical Properties of Discontinuous Fiber-Reinforced Composites

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Discontinuous fiber-reinforced composites (DFRCs) have attracted increasing attention in advanced manufacturing, aerospace, and automotive industries due to their high specific strength, design flexibility, and low-cost manufacturability. Compared with continuous fiber composites, DFRCs offer superior formability for complex geometries and are well suited for mass production via injection molding and compression molding. However, their mechanical behavior is strongly influenced by fiber-end effects and heterogeneous fiber orientation distributions, leading to pronounced nonlinearity and uncertainty in macroscopic properties. Accurate and efficient prediction of their mechanical performance therefore remains a critical challenge for large-scale engineering applications.

Conventional prediction methods, including analytical micromechanics models and finite element simulations, either suffer from limited accuracy due to oversimplified assumptions or incur prohibitive computational costs when resolving complex microstructures. To address these limitations, this study proposes a multimodal deep learning framework for predicting the mechanical properties of DFRCs, and the overall workflow of the proposed approach is illustrated in Figure 1. High-resolution representative volume element datasets are generated using a fast Fourier transform (FFT)-based solver to capture detailed microstructural responses [1]. A multimodal neural network is then developed to fuse microstructural image information with material parameter inputs, enabling robust learning of structure–property relationships. Furthermore, a transfer learning strategy is employed to efficiently adapt the model to different material systems using only limited additional data [2]. The proposed framework achieves high prediction accuracy and computational efficiency, providing a scalable and generalizable solution for DFRC mechanical property prediction and materials design.

References

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Figures

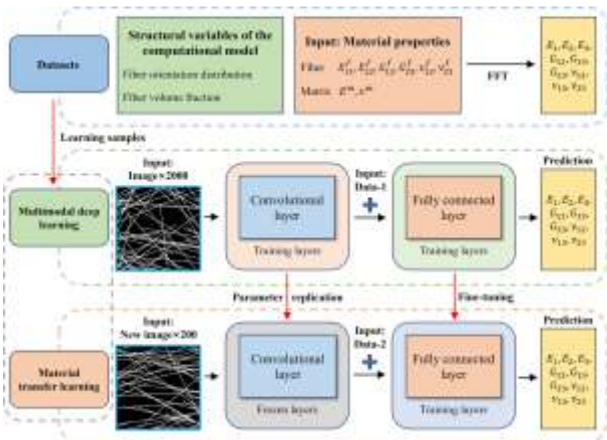

Figure 1. Overall workflow of the proposed multimodal deep learning framework for mechanical property prediction of DFRCs.